Erickson, C. M. 1982

The use of otolith sections for determining ages and back calculating lengths of walleyes, *Stizostedion vitreum*.

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ABSTRACT

Otolith sections were used to determine ages of walleyes collected from four Manitoban lakes. In order to validate presence of annuli on walleye otolith sections, ages determined from otolith sections were compared to corresponding ages derived from dorsal spine sections and scales, mean body lengths back calculated from 252 otolith sections were compared to mean observed lengths, and otolith sections from known age walleyes were aged.

Otolith sections can provide accurate age estimates and back calculated length estimates for young walleye populations. Otolith sections are less difficult to age and consequently more accurate for determining ages of old walleye individuals than scales and dorsal spines.

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INTRODUCTION

Thin sections of otoliths have been used by Beamish (1979), Power (1978), Campbell and Babaluk (1979), and Erickson (1979), for determining ages of various fish populations. The majority of otolith annuli were distinct using the section technique in the above studies. Otolith sections were used in this study for determining ages of walleyes collected from four Manitoban lakes. Mean ages determined from otolith sections were compared to corresponding ages derived from dorsal spine sections and scales. Mean back calculated body lengths from 252 otoliths were compared to mean observed lengths. Also, otolith sections from known age walleyes were aged.

The objectives of this study were:

1. to compare ages determined from otolith sections to ages determined from scales and dorsal spines.
2. to validate presence of annuli on walleye otolith sections through the use of known age walleye and back calculations of otolith sections.
3. to verify whether otolith sections provide an accurate method of age determination for walleyes.
4. to determine whether otolith sections provide accurate back calculated estimates of lengths.

DESCRIPTION OF STUDY AREA

The south basin of Lake Winnipeg is defined as that portion of Lake Winnipeg south of Grindstone Point (Fig. 1). The south basin has a area of 2,780 km^2 and an average depth of 9.7 meters (Brunskill *et al.* 1979). Walleyes have been commercially fished since the 1880's on southern Lake Winnipeg (Bilan 1974). The south basin is sedimentary and walleyes are heavily exploited by the commercial fisheries (Brunskill *et al.*, 1980,Lysack 1979, 1980).

Chitek Lake ($52^{o}25'N$ $99^{o}25'W$) (Fig. 1), is a sedimentary lake .8288 hectares in area, with an mean depth of 2.4 meters (unpublished data Province of Manitoba). Walleyes were never netted in Chitek Lake prior to 1977 (Province of Manitoba unpublished data). Commercial production was limited to pike in the 1960's. 2.4 million walleye fry were stocked into Chitek Lake by the Provincial Fisheries Branch in the spring of 1977.

Eardley Lake ($52^{o}32'N$ $96^{o}06'W$) and Obukowin Lake ($51^{o}04'N$ $95^{o}11'W$) are oligotrophic lakes and are located in the Precambrian Shield. Eardley Lake is 1889 ha. with a mean depth of 4.0 m and is located on the Poplar River system. Obukowin Lake is 1,692 ha. with a mean depth of 3.0 m and is located on the Gammon River system. Walleye populations found in these two lakes are considered lightly exploited as a commercial fishery does not take place on the two lakes and sports fishing is considered light.

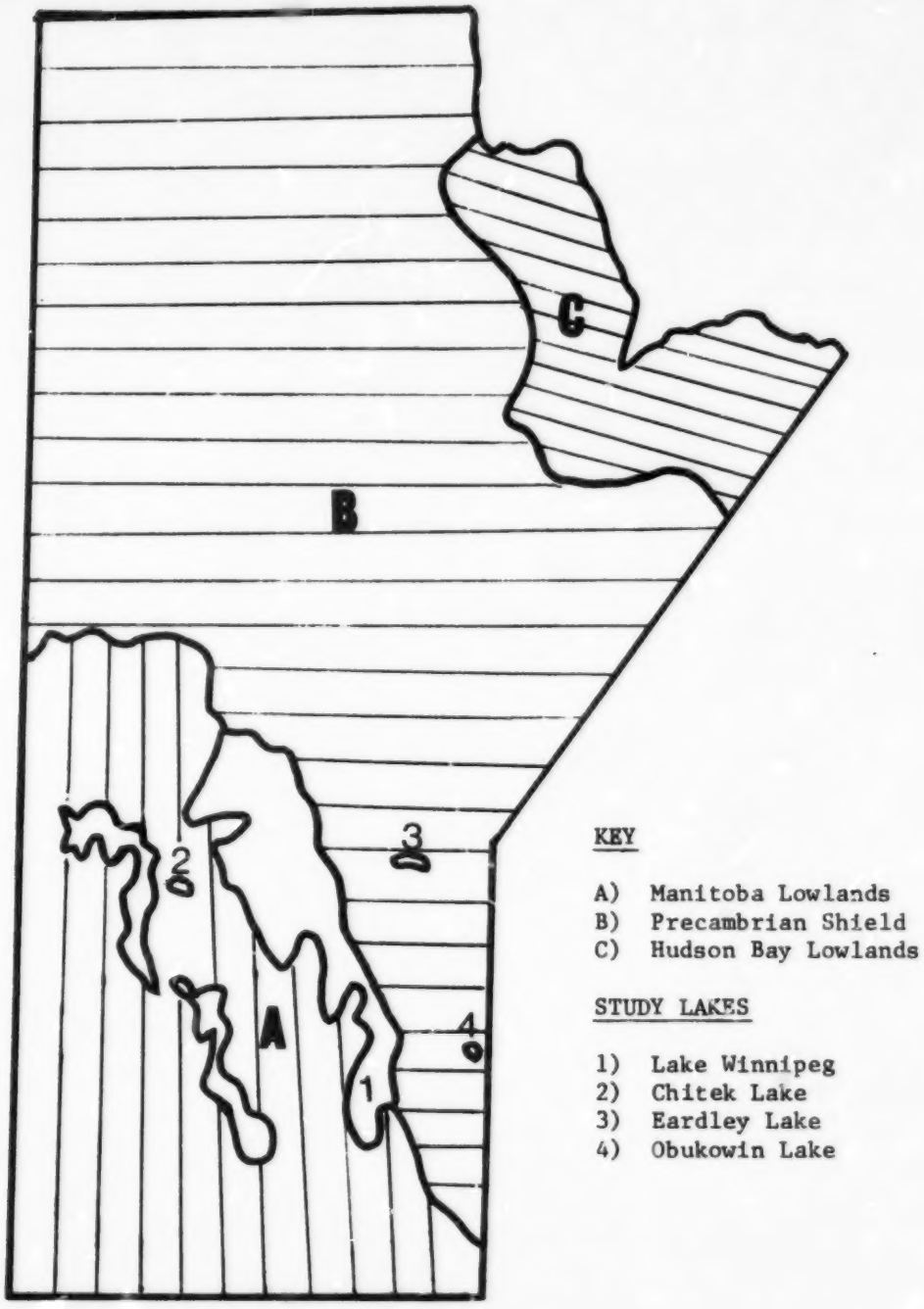


Fig. 1. Geology and location of study lakes.

METHODS AND MATERIALS

Numbers of walleyes sampled from each lake and sampling dates were as follows:

Lake Winnipeg - 252 - May 1981

Chitek Lake - 100 - Aug. 1980

Eardley Lake - 264 - Aug. 1978

Obukowin Lake - 172 - June 1978

Walleyes were collected with the use of experimental gangs of gill nets. Mesh sizes ranged from 38 to 140 mm. Walleyes were also sampled from commercial catches from southern Lake Winnipeg. Otoliths, dorsal spines, and scales were collected for each fish with the exception of the Chitek Lake sample where dorsal spines were not collected. Ageing structures were sampled, prepared, and aged according to Erickson (1979) with the exception that all walleye scales were viewed at 48X. Two experienced readers with the Provincial Fishery Branch were used to age all structures. Any structure yielding differences in ages was reread simultaneously by both readers and was omitted from further analysis if the age disagreement persisted. Percent agreements between readers were calculated. Otolith annulii were measured according to Beamish (1979). Back calculated lengths were calculated according to the following equation:

$$l_n = \frac{O_n}{O} \times l \qquad \text{(2) (Ricker 1968)}$$

where l_n = back calculated length of fish at annulus 'n'

l = present length of sampled fish

O_n = radius of annulus 'n'

O = present sampled otolith radius

It was assumed that the outer edge of each otolith represented a fully formed annulus, i.e. a fish aged 4+ years was considered to be 5 years old.

RESULTS

Lake Winnipeg

Ageing structures collected from southern Lake Winnipeg walleyes had well defined annuli. Otolith section mean ages were similar to mean ages derived from dorsal spines and scales (Figs. 2, 3, Tables 1, 2). The southern Lake Winnipeg walleye sample consisted mainly of young age classes (1 - 9). Percent agreements between readers for all ageing structures were high (Table 3).

Least squares regression analysis of otolith radii and body lengths of 252 walleyes from southern Lake Winnipeg (Fig. 4) resulted in the following equation:

$$Y = 3.53 + 0.142X \quad (1)$$

where Y = otolith radius (mm)
X = fork length (mm)

This relationship was highly significant ($F = 1385.88$ d.f. = 1 and 251, $r = 0.92$). The correlation coefficient, 0.94, of a log - log transformed plot was not significantly higher than that of the un-transformed plot.

Since the body size: otolith size relationship intercepted the abscissa extremely close to the origin and since a full log transformation did not significantly improve the correlation coefficient, it was assumed that the body size: otolith size relationship was linear and intercepted the axes at the origin.

Observed mean lengths of one and two year old walleyes were less than corresponding back calculated mean lengths at those ages. Observed mean lengths of fish aged three years and older were greater than corresponding back calculated mean lengths. Differences between observed and back calculated mean lengths at any age were not significantly different (Fig. 5, Table 4).

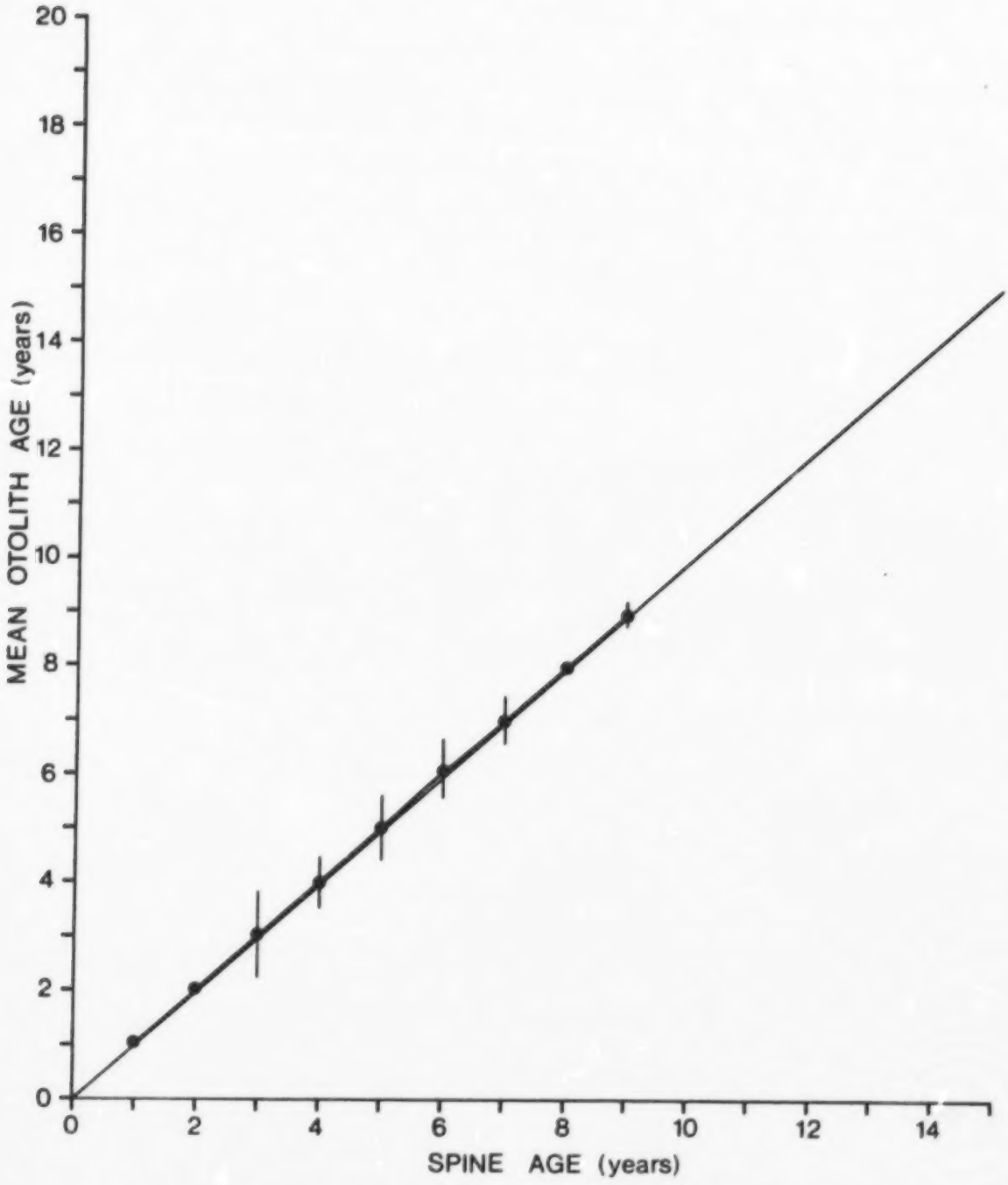


Fig. 2. Lake Winnipeg mean walleye ages showing comparisons between otolith sections and dorsal spine sections. Vertical bars are $\pm$ 2 S.D. about the age-specific mean otolith age.

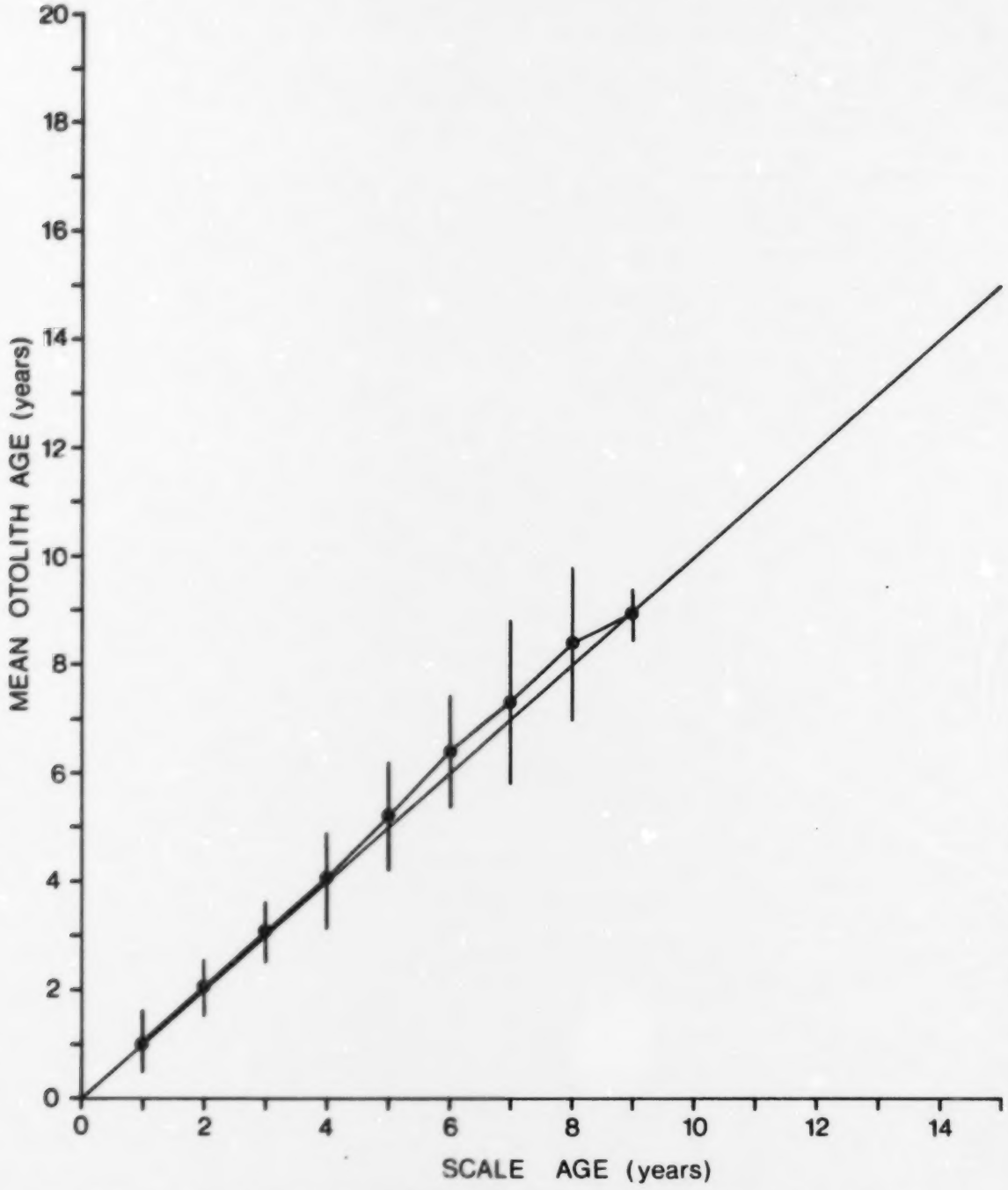


Fig. 3. Lake Winnipeg mean walleye ages showing comparisons between otolith sections and scales. Vertical bars are $\pm$ 2 S.D. about the age-specific mean otolith age.

Table 1. Comparison of dorsal spine ages and mean otolith ages of walleyes collected from Lake Winnipeg, Lakes Eardley and Obukowin.

Lake	Dorsal spine age (years)	Mean otolith age (years)	2 S.D.	Sample size
Lake Winnipeg	1	1.00	0,0	13
	2	2.00	0,0	30
	3	3.02	2.27,3.77	52
	4	4.00	3.54,4.46	41
	5	5.00	4.42,5.58	25
	6	6.07	5.58,6.63	15
	7	7.00	6.58,7.42	43
	8	8.00	0,0	5
	9	8.98	8.77,9.19	28
Eardley Lake	1	1.00	0,0	2
	2	2.00	0,0	7
	3	3.00	0,0	10
	4	4.00	0,0	14
	5	5.20	4.20,6.20	25
	6	6.05	5.60,6.50	36
	7	7.18	5.97,8.39	11
	8	9.45	6.00,12.90	47
	9	12.00	8.15,15.85	15
	10	13.38	8.61,18.15	8
	11	14.42	10.58,18.26	43
	12	15.77	12.20,19.34	31
	13	16.36	13.35,19.37	15
Obukowin Lake	1	1.00	0,0	1
	2	2.00	0,0	2
	3	3.00	0,0	5
	4	4.00	0,0	9
	5	5.31	4.20,6.40	24
	6	7.53	4.30,10.7	27
	7	9.42	5.20,13.6	20
	8	11.54	6.60,16.4	8
	9	13.00	8.80,17.2	24
	10	13.84	9.20,18.4	16
	11	15.12	11.60,18.6	20
	12	16.42	12.80,20.0	7
	13	17.00	13.35,20.65	7
	14	17.53	16.10,18.90	2

Table 2. Comparison of scale ages and mean otolith ages from walleyes collected from Lake Winnipeg, Lakes Eardley and Obukowin.

Lake	Scale age (years)	Mean otolith age (years)	2 S.D. (years)	Sample size
Lake Winnipeg	1	1.08	.53,1.63	13
	2	2.06	1.56,2.56	31
	3	3.08	2.54,3.62	54
	4	4.07	3.15,4.90	44
	5	5.20	4.20,6.20	27
	6	6.40	5.38,7.42	18
	7	7.33	5.83,8.83	40
	8	8.40	7.00,9.80	10
	9	8.95	8.49,9.41	15
Eardley Lake	1	1.00	0,0	2
	2	2.14	1.39,2.89	7
	3	3.20	2.36,4.04	10
	4	4.20	3.37,5.03	15
	5	5.82	4.38,7.26	50
	6	9.13	4.27,14.84	83
	7	13.54	9.21,17.87	50
	8	14.45	10.15,18.75	24
	9	16.42	11.78,21.06	23
Obukowin Lake	1	1.00	0,0	1
	2	2.00	0,0	2
	3	3.16	2.34,3.98	5
	4	4.30	2.95,5.65	10
	5	6.10	3.80,8.40	51
	6	12.42	7.52,17.30	72
	7	15.27	12.42,17.62	18
	8	16.54	12.74,20.34	13

Table 3. Frequencies (%) of agreement and disagreement for ages determined by two readers using otolith sections, dorsal spine sections, and scales.

Lake	Structure	Frequency of total agreement (%)	Frequency of disagreement (%) ± 1 yr.	± 2 yr.	± 3 yr.
Winnipeg	otolith	89.0%	11.0%		
	Dorsal spine	80.0%	15.8%	4.2%	
	scale	78.8%	16.7%	5.3%	
Chitek	otolith	93.0%	7.0%		
	scale	90.0%	10.0%		
Eardley	otolith	76.1%	20.9%	3.0%	
	spine	55.4%	29.5%	10.8%	4.3%
	scale	53.3%	27.4%	15.4%	3.9%
Obukowin	otolith	77.6%	17.4%	5.0%	
	spine	59.4%	24.3%	12.1%	4.2%
	scale	51.6%	25.4%	14.1%	3.9%

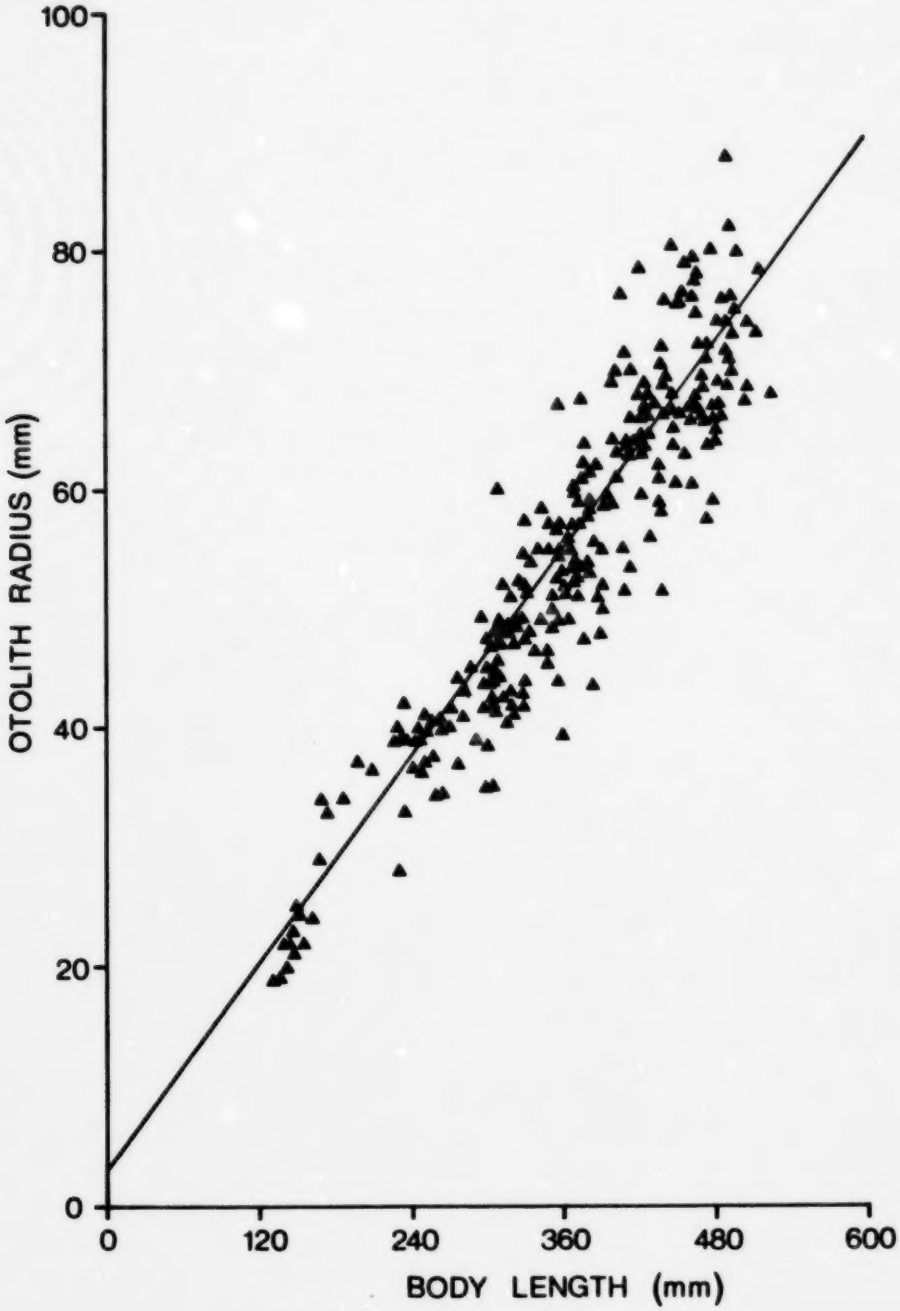


Fig. 4. Relationship of otolith section radius and body length for 252 walleyes sampled from southern Lake Winnipeg. At least 10 otoliths per age class are represented.

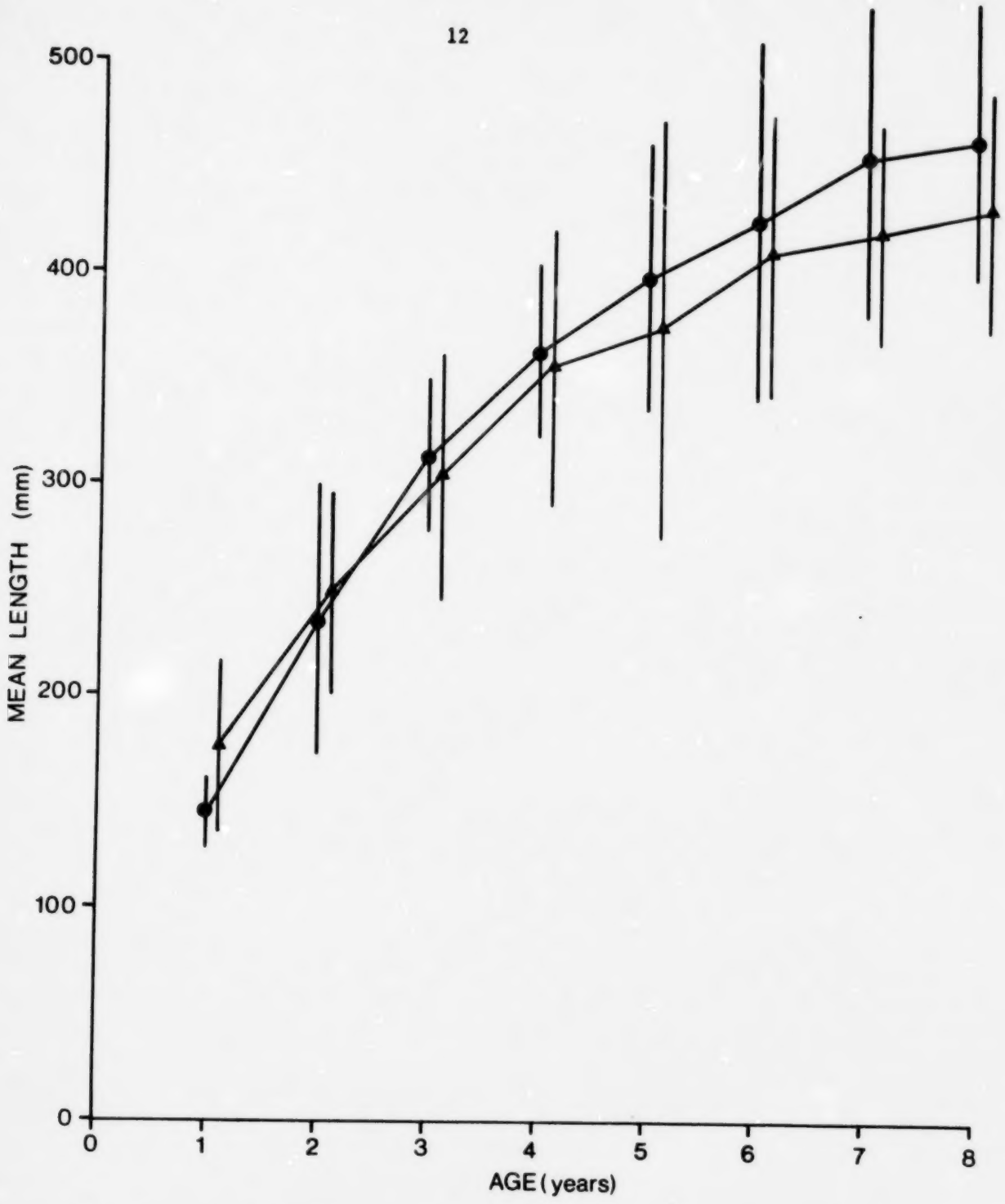


Fig. 5. Observed (●) and back calculated (▲) growth curves of Lake Winnipeg walleyes. Vertical bars represent ± 2 standard deviations about means.

Table 4. Comparison of observed mean lengths to back calculated otolith mean lengths for walleyes sampled from southern Lake Winnipeg. Enveloping numbers are ± 2 standard deviations.

Age	Sample size	Observed mean length	Back calculated mean length
1	13	127.76 < 144.00 < 160.23	136.30 < 176.10 <215.90
2	30	172.49 < 234.89 < 299.94	201.28 < 248.46 <295.64
3	52	278.05 < 313.66 < 349.27	245.61 < 303.57 <361.53
4	41	322.90 < 362.98 < 403.06	291.17 < 355.97 <420.77
5	25	335.54 < 398.44 < 461.34	275.50 < 374.02 <472.49
6	18	341.09 < 425.21 < 509.33	343.14 < 409.30 <475.46
7	43	380.68 < 455.11 < 526.54	367.93 < 419.21 <470.49
8	5	398.60 < 463.32 < 528.04	373.79 < 430.00 <486.21

Chitek Lake

Otolith and scale annuli were distinct and age comparisons and percent agreements between readers were similar (Table 3) . 96 walleyes were aged 3+ with otolith sections and 90 were aged 3+ with scales from the total 100 known age 3+ sample. Figure 6 shows a photograph of a known age 3+ walleye from Chitek Lake which validates the presence of 3 annuli on the otolith section.

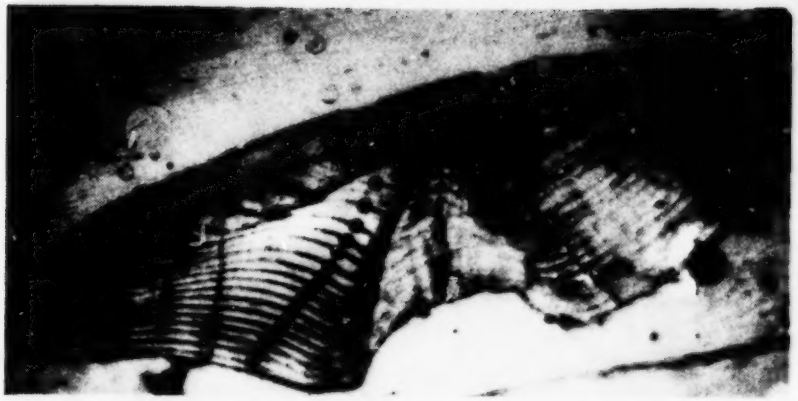
Eardley and Obukowin Lakes

Walleye otolith sections from Eardley and Obukowin lakes had well defined annuli (Fig. 7). Ageing difficulties were encountered with scale and to a lesser degree with dorsal spines (Fig. 7). Annuli were crowded at the edge of scales on the majority of walleyes older than 5+ - 6+. Similar ageing difficulties, although not as frequent as with scales, were encountered with the dorsal spine sections.

The otolith age composition of both lakes contained many old (10+ - 21+) individuals (Figs. 8-11, Table 1, 2). Mean ages derived from otolith sections were significantly older than mean ages derived from scales past age 6+ for Eardley Lake walleyes and past age 5+ for Obukowin Lake walleyes (Figs. 8, 9). Mean ages derived from otolith sections were significantly older than mean dorsal spine ages past age 11+ for Eardley Lake walleyes and 10+ for Obukowin Lake walleyes (Figs. 10, 11). Percent agreements between readers were significantly higher for otolith section ages than for both dorsal spine and scale ages (Table 3).

Fig. 6. An example of an otolith section from a known age 3+ walleye collected from Chitek Lake. (annuli indicated by circles).

-A-



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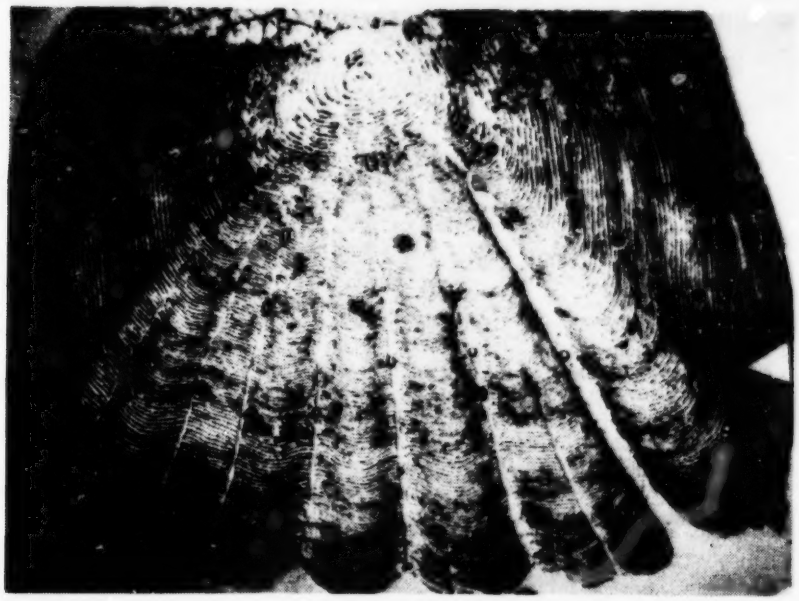

-C-

Fig. 7. Example of a otolith sections (A), a scale (B), and a dorsal spine section(C), from a walleye sampled from Eardley Lake. Visible annuli are indicated by circles and severe merging of annuli at the edge of the scale and dorsal spine section are indicated by a triangle.

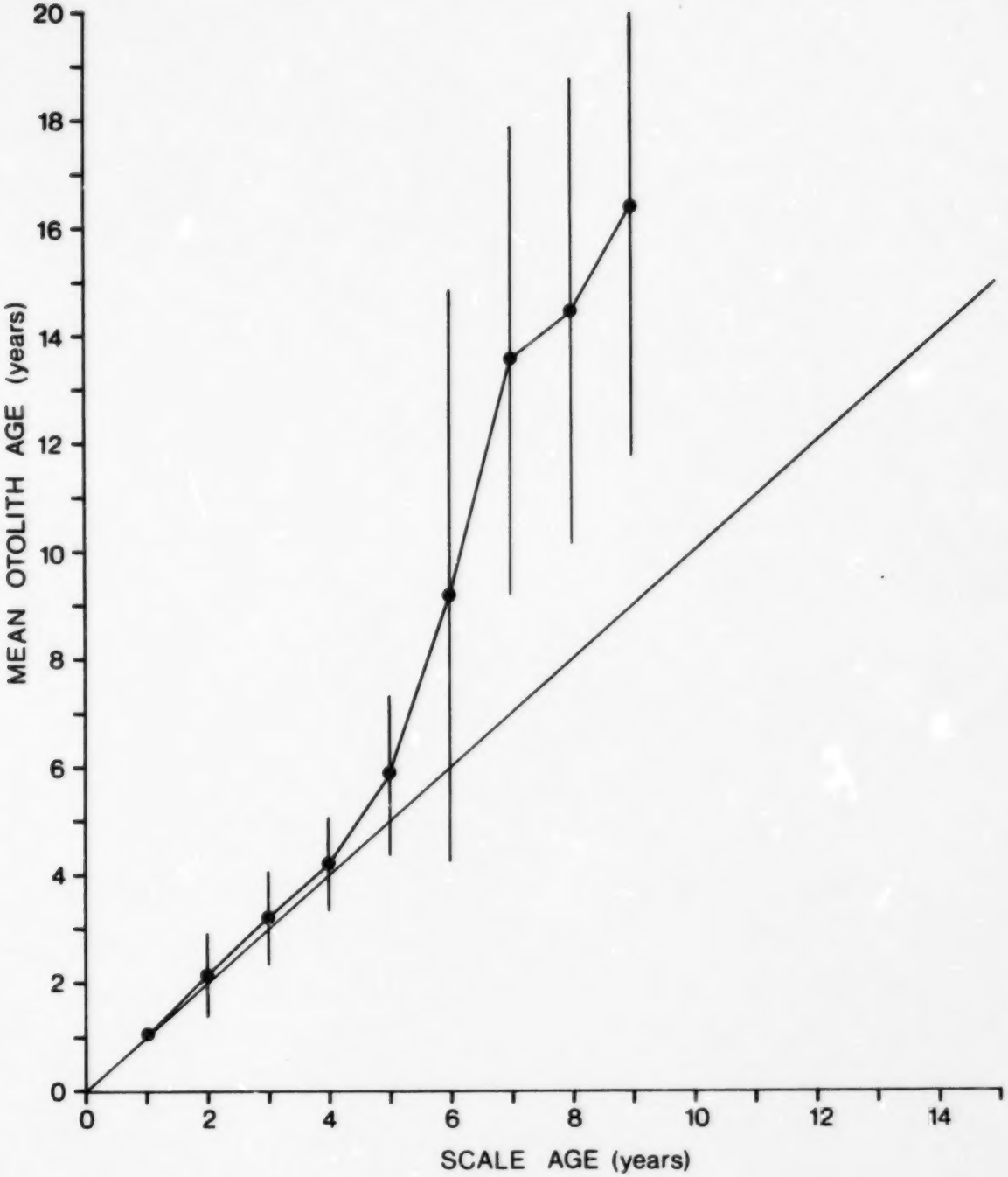

Fig. 8. Eardley Lake mean walleye ages showing comparisons between otolith sections and scales. Vertical bars are ± 2 S.D. about the age-specific mean otolith age.

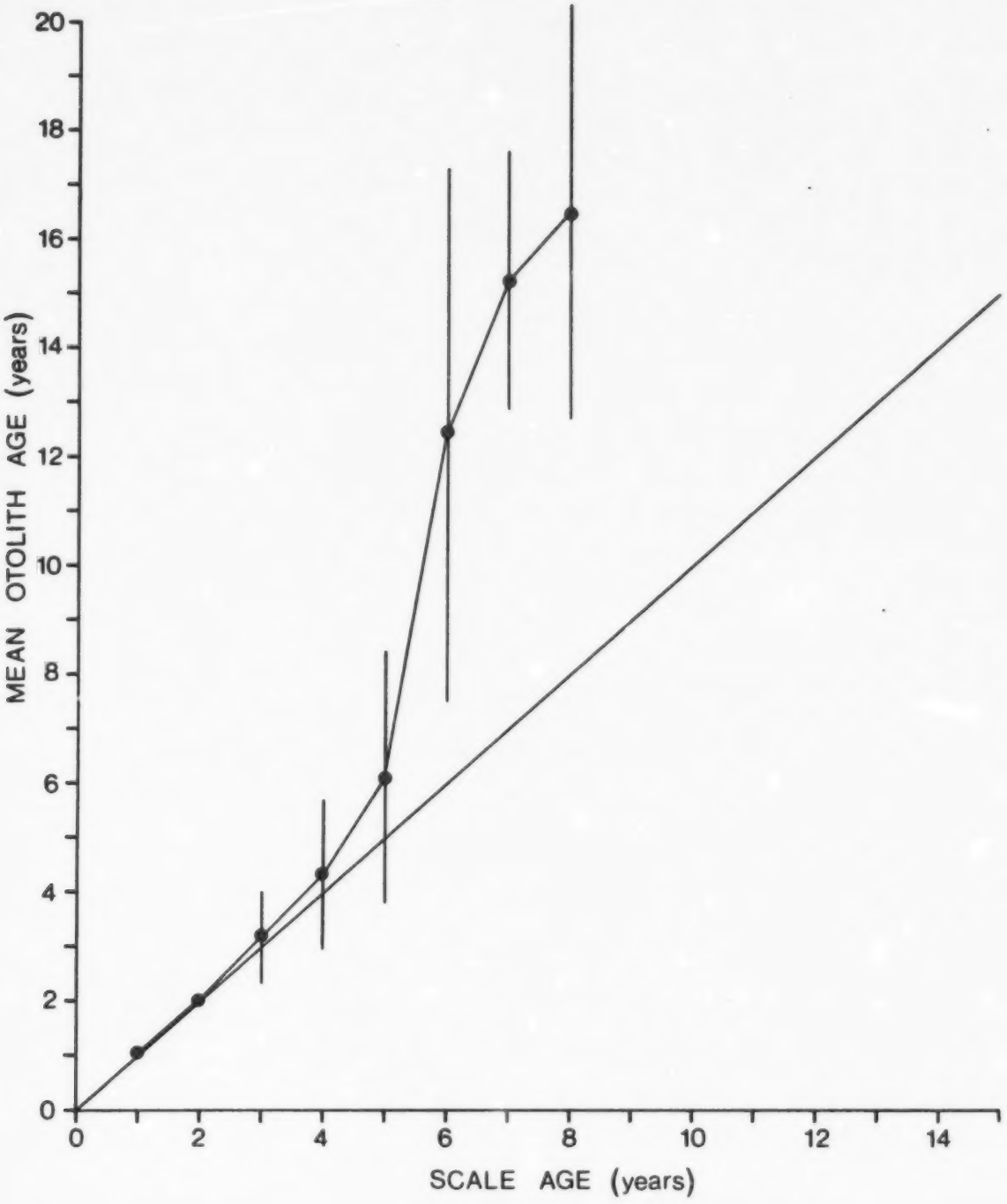

Fig. 9. Obukowin Lake mean walleye ages showing comparisons between otolith sections and scales. Vertical bars are $\pm$ 2 S.D. about the age-specific mean otolith age.

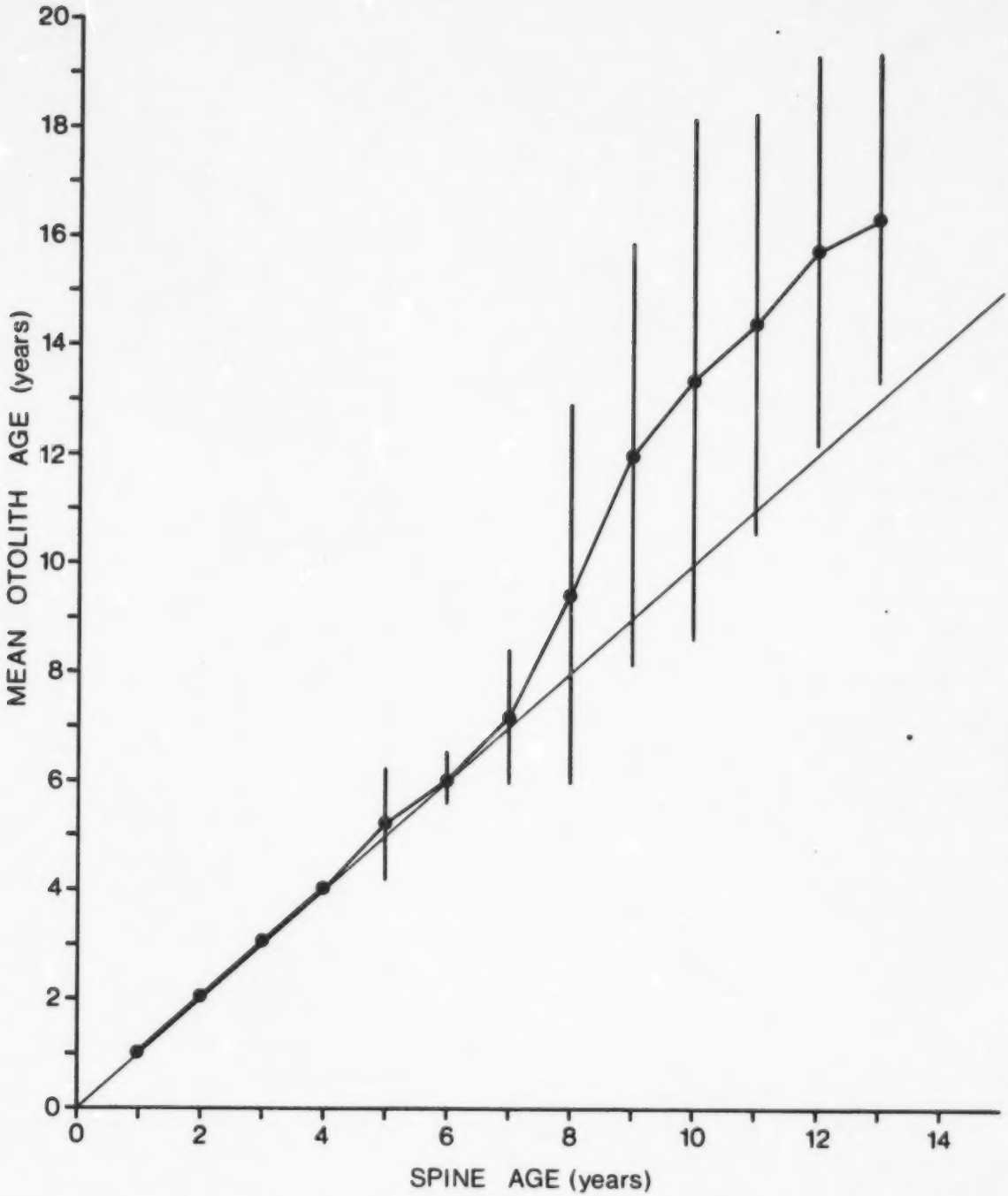

Fig. 10. Eardley Lake mean walleye ages showing comparisons between otolith sections and dorsal spine sections. Vertical bars are $\pm$ 2 S.D. about the age-specific mean otolith age.

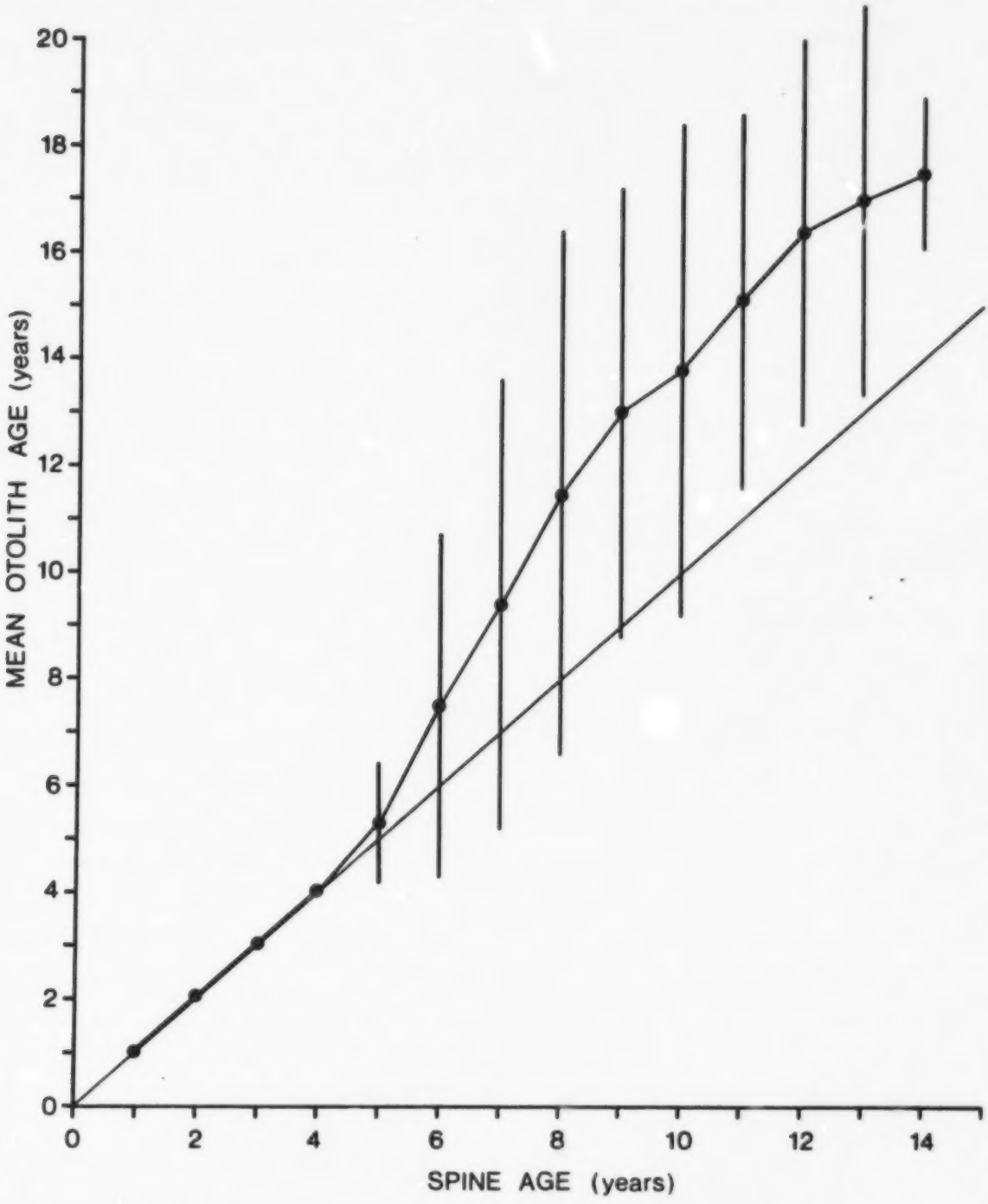

Fig. 11. Obukowin Lake mean walleye ages showing comparisons between otolith sections and dorsal spine sections. Vertical bars are ± 2 S.D. about the age-specific mean otolith age.

DISCUSSION

Lake Winnipeg

Ages derived from otolith sections were similar to ages derived from dorsal spines and scales (Figs. 2, 3, Tables 1, 2). The majority of walleyes aged in this sample were captured in their growing years before individual asymptotic sizes had been attained. Many of the walleyes collected were large and showed evidence of fast individual growth as ages were relatively young. The young age compositions and fast growth of southern Lake Winnipeg walleyes has been attributed mainly to the heavy exploitation of the commercial fishery (Lysack 1979, 1980). As a result, all annuli were well spaced and distinct on all ageing structures in this study and ages derived from otolith sections were similar to ages derived from dorsal spine sections and scales.

Back calculations of body lengths using otolith sections

Rosa Lee's phenomenon occurs when back calculations of length tend to be smaller, the older the fish from which they are computed. One-way analysis of variance and multiple range tests of mean back calculated lengths for each age derived from fish of various ages are not applicable since categories containing unequal numbers of observations are created (Table 5). However, a regression of back calculated lengths for a given age derived from fish of

Table 5. Age-specific lengths of walleyes back calculated from fish of successively increasing ages. Enveloping numbers under means are ± 2 standard deviations.

Annulus	Fish Age (years)								
	1	2	3	4	5	6	7	8	9
1	145.92	162.46	167.19	175.05	187.28	188.43	188.32	192.60	175.16
	129.68,162.16	122.67,202.25	127.32,207.96	145.71,204.39	155.79,218.77	148.72,228.14	149.20,227.42	174.51,210.63	140.58,209.74
2		234.83	244.29	246.50	258.85	255.21	257.02	249.40	236.29
		173.52,296.14	213.33,275.25	199.92,293.08	216.40,301.30	197.72,312.70	209.73,304.31	222.62,276.18	189.97,282.60
3			313.66	307.33	311.12	308.50	317.60	294.20	277.86
			278.05,349.27	272.27,342.39	266.30,356.22	237.75,379.25	260.13,357.17	265.00,323.40	236.40,319.34
4				362.98	354.60	349.64	353.10	334	319.18
				322.90,403.06	408.29,408.29	267.46,431.80	289.8 ,416.40	299.53,368.47	275.15,363.21
5					376.50	386.14	397.63	371	358.00
					302.41,450.10	301.19,471.09	324.84,470.43	325.72,416.28	311.55,404.45
6						425.20	432.42	401.4	391.89
						341.09,509.33	356.81,508.03	352.23,450.57	344.42,439.36
7							455.00	431.40	417.00
							380.68,526.54	382.23,491.97	367.58,466.42
8								463.32	417.04
								398.60,528.04	367.62,466.46

varying ages plotted against the ages of the fish should have a slope = 0 if Rosa Lee's phenomenon is not occurring. Regression analyses of such plots (Fig. 12), revealed the presence of Rosa Lee's phenomenon in curve 4 and reverse Rosa Lee's phenomenon in curve 1 (Table 6). Curve 3 to 7 (Fig. 12) were characterized by decreasing slopes although most of the slopes were not significantly different from 0 at P = 0.05 because the number of the observations decreased from curve to curve (Table 6). This trend of decreasing slopes indicates Rosa Lee's phenomenon which may be due to size-selective fishing mortality (Ricker 1968).

Differences between growth parameters estimated from observed and back calculated mean lengths using both the exponential and von Bertalanffy growth models were not significant (Table 7). However, the exponential growth rate and L_{∞} estimated from observed data were slightly greater than their corresponding back calculated counterparts. The observed Brody growth coefficient was greater than the back calculated Brody growth coefficients. The observed t_o correction value was substantially less than its back calculated counterpart.

Chitek Lake

Otolith sections and scales were accurate in determining ages of known age walleyes collected from Chitek Lake. Marks interpreted as annuli on the otolith section were valid (Fig. 6). Annuli were distinct on both structures due to the fast growth and young age composition of walleyes examined. Marks interpreted as annuli on the known age otolith sections were similar to marks interpreted as annuli on otolith sections from the other 3 walleye populations examined (Figs. 6, 7).

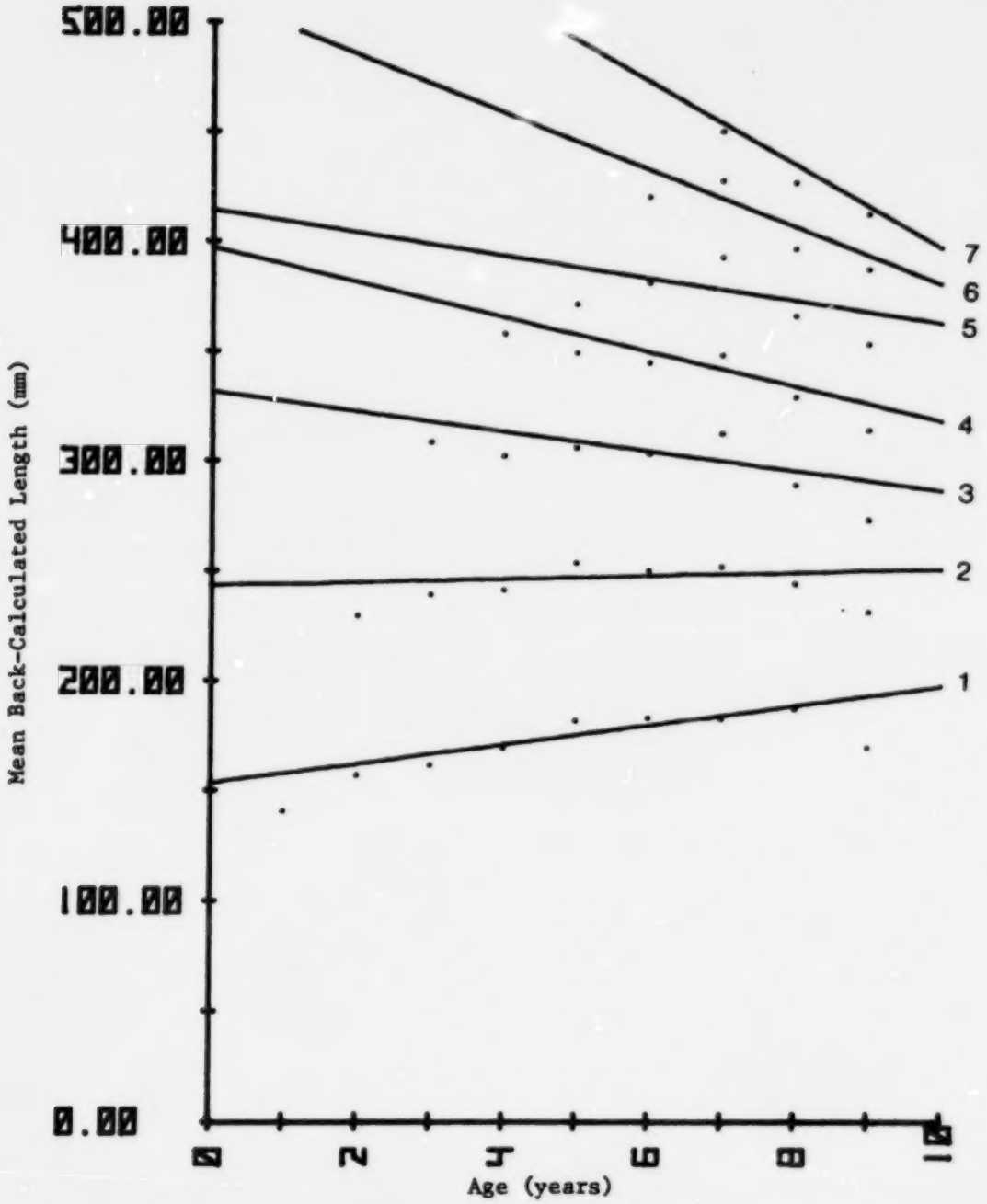

Fig. 12. Age-specific mean lengths of walleyes back calculated from fish of successively decreasing (curve 1-7) ages.

Table 6. Regressions testing for the presence of Rosa Lee's phenomenon. When the slope is significantly different from zero, the phenomenon is present.

Curve for back calculated length at annulus	Equation	Correlation coefficient	Test F ratio and d.f.	Significance at P = 0.05
1	Y = 153.905 + 4.384X	0.784	11.16(1.7)	significant
2	Y = 243.629 + 0.758X	0.205	0.26(1,6)	non significant
3	Y = 331.577 - 4.542X	0.712	5.15(1,5)	non significant
4	Y = 397.089 - 7.924X	0.924	23.21(1,4)	significant
5	Y = 414.352 - 5.214X	0.549	1.29(1,3)	non significant
6	Y = 510.940 -13.095X	0.880	6.90(1,2)	non significant
7	Y = 586.467 -19.000X	0.990	51.18(1,1)	non significant

Table 7. Exponential and von Bertalanffy growth curves determined from observed and back calculated age-specific mean lengths.

Curve	Data type					
	Observed			Back-calculated		
	Equation	Correlation coefficient	Test F ratio and d.f.	Equation	Correlation coefficient	Test F ratio and d.f.
Exponential growth	$Y = 5.047 + .565X$	.989	259.20(1,6)	$Y = 5.208 + .439X$	.993	411.13(1,6)
Walford plot	$Y = 132.832 + .738X$	.998	1101.17(1,5)	$Y = 120.967 + .741X$	.993	344.81(1,5)
$\text{Log}_e(L_\infty - l_t)$ versus t	$Y = 6.210 - .309X$	.998	1659.95(1,6)	$Y = 5.974 - .301X$	.997	989.16(1,6)
Von Bertalanffy growth	$l_t = 506.992\ (1 - e^{-.309(t + .0599)})$			$l_t = 467.054\ (1 - e^{-.301(t + .5729)})$		

Eardley and Obukowin Lakes

Age results from Eardley and Obukowin lakes showed similar characteristics. Several old walleye individuals (10+ - 22+) were prevalent in the age composition of both lakes using otolith section ages (Figs. 8-11, Tables 1, 2). Walleyes collected from Eardley and Obukowin lakes were smaller in size than walleyes collected from southern Lake Winnipeg. Studies have shown that walleyes from Eardley and Obukowin lakes have a slower growth rate and a smaller asymptotic size than walleyes from southern Lake Winnipeg (Hagenson and O'Connor 1979, 1981; Lysack 1979, 1980). Since scale growth is approximately isometric to body growth, it follows that outer annuli of walleye scales from Eardley and Obukowin lakes should be crowded.

Otolith sections were considered superior for determining ages of older walleyes as annular crowding at the edge of the otolith sections was not as pronounced as it was on scales and dorsal spines. Annuli did not crowd together on any of the ageing structures of younger (1+ - 6+) walleye individuals collected from Eardley and Obukowin lakes. This factor could be the result of faster individual growth which occurs in earlier years. As a result, otolith section ages were similar to scale and dorsal spine age results for younger walleyes.

The presence of annuli on walleye otolith sections was validated on back calculation results from southern Lake Winnipeg and known age results from Chitek Lake (Figs. 4-6). Otolith sections can provide fishery managers with an accurate age estimation for young walleye populations and may prove to be less difficult to age and consequently more accurate for determining ages of old walleye individuals than scales and dorsal spine sections.

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